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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new non-provisional applications under 37 CFR 1.53(b))

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First Named Inventor or Application Identifier			
Salman Akram, et al.			
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APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents

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1. ☒ Fee Transmittal Form
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2. ☒ Specification Total Pages 28
(preferred arrangement set forth below)
 - Descriptive
 - Cross References to Related Application
 - Statement Regarding Fed sponsored R & D
 - Reference to Microfiche Appendix
 - Background of the Invention
 - Brief Summary of the Invention
 - Brief Description of the Drawings (if filed)
 - Detailed Description
 - Claim(s)
 - Abstract of the Disclosure
3. ☒ Drawing(s) (35 USC 113) Total Sheets 27
Total Pages 9
4. Oath or Declaration
 - a. ☐ Newly executed (original or copy)
 - b. ☒ Copy from a prior application (37CFR 1.63(d))
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[Note Box 5 below]
 - i. ☒ DELETION OF INVENTOR(S)
Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
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The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. ☐ Microfiche Computer Program (Appendix)
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ACCOMPANYING APPLICATION PARTS

8. ☐ Assignment Papers (cover sheet & document(s))
9. ☒ 37 CFR 3.73(b) Statement ☒ Power of Attorney
(where there is an assignee)
10. ☐ English Translation Document (if applicable)
11. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
12. ☒ Preliminary Amendment
13. ☒ Return Receipt Postcard (MPEP 503)
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Statement(s) Status still proper and desired
15. ☐ Certified Copy of Priority Document(s)
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Salman Akram, David R. Hembree and
Warren M. Farnworth

Serial No.:

Filed: August 31, 2000

For: ELECTRICAL CONNECTOR

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§ Examiner:
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PRELIMINARY AMENDMENT

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After awarding the above-captioned application the benefit of the priority date of its parent -
- application #09/265,906, filed March 10, 1999 -- please amend the current application as follows.

IN THE SPECIFICATION:

Immediately after the title, please add the following: --

Related Application

This application is a divisional of application serial number 09/265,906, filed March 10,
1999. --

IN THE CLAIMS:

Please cancel claims 1-51 and 55-62 without prejudice.

REMARKS

Claims 52-54 are the only claims pending as of this First Amendment and Election. In a restriction requirement issued in the parent case as part of the Office Action of April 28, 2000, the Examiner identified these claims as "Group II" claims "drawn to method of making a socket contact, classified in class 29, subclasses 825, 832, 842, and 874."


Applicants will pursue the canceled claims in related applications and therefore request that those claims be canceled without prejudice.

Because of the cancellation of claims, Applicants are concurrently filing a Statement Concerning Deletion of Inventors.

If there are any matters which may be resolved or clarified through a telephone interview, the Examiner is requested to contact Applicants' undersigned attorney at the number indicated.

Respectfully submitted,

Date: 8/29/00


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DOCKET NO.: 97-1102

APPLICATION FOR LETTERS PATENT

FOR

ELECTRICAL CONNECTOR

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ELECTRICAL CONNECTOR

Technical Field

5 The present invention relates generally to devices and methods for providing electrical connection between two electronic components. More specifically, the present invention relates to a socket contact configured to establish electrical communication between a semiconductor die and a test device as well as methods for forming the socket contact.

Background of the Invention

10 Testing a semiconductor die often involves establishing an electrical connection between testing equipment and the circuitry of a die. Testing may be performed on an
15 unpackaged die that has been singulated from a semiconductor wafer, on a section of dies that are still part of the wafer, or on all of the dies on a wafer. Moreover, a bare die that has undergone packaging steps may also be tested. One example of such a die is a “flip chip,” wherein conductive material such as solder balls are attached directly to the bond pads or electrical traces formed in the surface of the die; the die is then “flipped,” or
20 mounted face down, so that the solder balls may connect with contact members of another device. Another example is a “chip scale package,” which includes a die along with one or more package elements, such as encapsulating material in the form of thin protective coatings formed of glass or other materials bonded to the face and backside of the die; in addition, solder balls may be attached to electrical traces in the surface of the
25 die or directly to the die’s bond pads through openings in the encapsulating material. A Ball Grid Array (BGA) serves as yet another example that involves even more packaging: the die is wire bonded to the top of a substrate, encapsulated, and solder balls are bonded to electrical traces at the bottom of the substrate that lead to the wirebonds.

The device to be tested will hereinafter be referred to as an integrated circuit chip, or IC chip, regardless of the singulation or packaging state of the die that forms all or part of the IC chip. One method of testing the IC chip involves placing the chip into a socket, which comprises a body with holes that span through the body. These holes house

5 contacts that are aligned with electrical contact points of the IC chip. For purposes of explanation only, it will be assumed that the contact points of the IC chip are solder balls. Often, the socket includes a lid that, when closed, pushes the solder balls of the IC chip against the heads of the socket's contacts. Once the IC chip has been inserted, the socket is then plugged into a printed circuit board (PCB). This insertion often involves a biasing
10 force in the opposite direction of the lid's pushing force. To ensure electrical communication between the IC chip and the PCB without the risk of breaking the socket contacts, the socket contacts are configured to be resilient to the compression resulting from these forces. One such configuration for doing so involves the use of "pogo pin" contacts. A pogo pin can comprise an electrically conductive inner shaft, an electrically
15 conductive outer shell concentric to the shaft and defining the head of the contact, and an electrically conductive spring between the inner shaft and outer shell. When the pogo pin undergoes compression, the inner shaft is pushed into the outer shell despite the spring's bias. Ideally, signals received at the head of the outer shell will conduct through the spring to the inner shaft and onward to devices that may be connected to the inner shaft.
20 However, such a design allows for unneeded electrical communication along the entire surface of the outer shell.

As an alternate configuration, buckle beams may be used. Buckle beams are essentially a thin, somewhat rigid length of conductive material that will buckle in
25 response to compression from the IC chip and the PCB being pushed toward each other. The problem with buckle beams is that the holes housing the beams must be wide enough to accommodate the horizontal motion of the beams as they buckle. The buckling space required limits the density of beams per unit area that can be achieved. In addition,

buckle beams tend to rotate during buckling. Thus, in certain aspects, pogo pins and buckle beams run contrary to the needs in the art for electrical contacts that require minimal space and material.

5 Returning to the testing process, the PCB with the connected socket is placed in a chamber, wherein the IC chips are tested while subjected to an elevated temperature. Such testing is referred to as burn-in testing. The socket's contacts provide electrical communication between the IC chip and signals sent through the PCB from the test equipment. Once the test is complete, the chip is removed from the socket. IC chips
10 which do not pass the testing are discarded, and chips that pass may undergo further testing and ultimately be used as components in electronic devices.

 Further testing and use of these chips, however, depends upon the ability of the solder balls to continue to function after their interaction with the socket's contacts. Prior
15 art socket contacts have heads that are configured through their flexibility to actively exert a force against the chip's solder balls, wherein the force is generally transverse to the biasing force that pushes the chip into the socket. The effect of this transverse force is to pinch the solder balls, thereby severely damaging them and making further communication with the chip difficult. Such socket contacts include the aptly named
20 "pinch contact" found in the Series 655 OTBGA Burn-in/Test Socket sold by Wells Electronics. Another series 655 OTBGA Socket by Wells uses a Y-shaped contact. The Y-shaped contact is further described in United States Patent 5,545,050, by Sato et al., indicating that the head of the Y-shaped contact is flexible, which allows it to "snugly" accommodate a hemispherical conductor of an IC package. (Sato at col. 4, ln. 25-30.)
25 Thus, the Y-shaped contact continues the tradition of applying a pinching action to the electrical contacts of a device.

 Still other examples of contact heads are illustrated by references from Interconnect Devices, Inc. (IDI). Among the examples are plunger probe tips having
30 crown-shaped heads, whose sharp prongs tend to gouge the surface of the chip's contact,

be it a solder ball or flat pad. In addition, IDI discloses a concave tip that might accommodate hemispherical chip contacts such as solder balls, but may provide insufficient electrical communication for other contacts, such as those configured as flat pads.

5 Thus, in addition to the needs in the art discussed above concerning the body of an electrical connector, there is also a need in the art for an electrical connector having a head that reduces the damage to the electrical contacts of IC chips during connection and is configured to accommodate more than one type and size of chip contact. More specifically, there is a need in the art for a socket contact that minimizes the damage to
10 various IC chip contacts during IC chip testing.

Summary of the Invention

Accordingly, the current invention provides electrical contacts as well as methods
15 for forming them. One preferred embodiment comprises a contact as part of a socket used for testing semiconductor die, wherein the contact has a head that defines a recess, and the head is coupled to an elongated conductive body configured to fit within a socket. More specifically, the head comprises a portion defining the perimeter of the head, with other portions of the head lower than the perimeter. In one exemplary embodiment, this
20 head takes the form of a planar ring with a sidewall sloping downward from the ring toward the central axis running the length of the contact. This sidewall transitions to a generally planar section that is parallel to, yet lower than, the perimeter ring. Various preferred embodiments address varying degrees of transition and planarity of the portions of the contact head.

25 Other preferred embodiments address the body of an electrical contact, including one embodiment comprising a head, a shaft, and a spring coupling head to the shaft. In a more specific embodiment, the spring's coils define circles of differing circumferences. Another exemplary preferred embodiment comprises a metallic tube for the contact body,
30 wherein the tube defines at least one slit. Yet other preferred exemplary embodiments

address silicon contacts and methods for forming them. Specifically, semiconductor fabrication techniques are used to define an array of silicon contacts, and the contacts are singulated while maintaining their alignment within the array.

5 Still other preferred embodiments include the recessed contact head as described above in combination with the contact bodies just described. These embodiments include methods and devices wherein the head is formed separately from the body and attached thereto, as well as methods and devices wherein the head is integral to the body.

10 Brief Description of the Drawings

Figure 1 is a cross-sectional view of one exemplary embodiment of the current invention.

Figure 2 is a close-up view of a portion of Figure 1.

15 Figure 3 is a top-down view of the illustration in Figure 2.

Figures 4A and 4B are top-down views of a second and third exemplary embodiment of the current invention.

Figures 5A and 5B are cross-sectional views of fourth and fifth exemplary embodiments of the current invention.

20 Figures 6A-6D are cross-sectional views of sixth, seventh, eighth, and ninth exemplary embodiments of the current invention.

Figure 7 is a cross-sectional view of a tenth exemplary embodiment of the current invention.

25 Figure 8 is a cross-sectional view of an eleventh exemplary embodiment of the current invention.

Figure 9 is a cross-sectional view of a twelfth exemplary embodiment of the current invention.

Figure 10 is a cross-sectional view of a thirteenth exemplary embodiment of the current invention.

Figure 11 is a cross-sectional view of a fourteenth exemplary embodiment of the current invention.

Figure 12A-E are cross-sectional views of an additional exemplary embodiments of the current invention.

5 Figures 13A-13H illustrate steps of another exemplary embodiment of the current invention.

Figures 14A-14C depict alternate steps of yet another exemplary embodiment of the current invention.

10 Figures 15A-15C illustrate alternate steps of still another exemplary embodiment of the current invention.

Detailed Description of the Preferred Embodiments

Figure 1 depicts one exemplary embodiment of the current invention in the context of testing an IC chip. IC chip 20, which could be a bare die, a flip chip, a chip scale package, or a die at any stage of packaging, is enclosed within a socket 22. The socket 22 comprises a body 24 made of electrically non-conductive material as well as a holding mechanism 26 for biasing the IC chip 20 against the body 24. In this particular example, the holding mechanism 26 is a pair of hinged lids, but those skilled in the art know that there are many ways to position the IC chip 20. In this position, the IC chip's contacts 28, which are assumed to be solder balls for purposes of explanation, are aligned with holes 30 extending in generally one direction through the body 24. Socket contacts 32 extend through these holes 30 and electrically connect the chip's contacts 28 and the PCB 34. Each socket contact body 36, depicted in an exemplary generic form in Figure 1, is configured to be resilient along an axis defined by the biasing force that pushes the PCB 34 against the socket contacts 32. This axis is often referred to as the "z-axis" and is further described below. Such resiliency can be achieved through known methods, such as with pogo pins or buckle beams, or through embodiments of the current invention which will be described below.

The head 38 of each socket contact 32 is configured to receive a chip contact 28. Contrary to the prior art contacts which have heads in the form of spears, chisels, needles, crowns, or pinchers, exemplary embodiments of the current invention include socket contacts having heads that define grooves or recesses or cavities or cups. Figure 2, for example, is a close up of the socket contact head 38 depicted in Figure 1. In this cross-sectional view, one can see that the socket contact head 38 comprises a first portion 40 defining a plane 41 and an opening. In this embodiment, the plane 41 is parallel to the IC chip 20 positioned within the socket 22. Similarly, a second portion 42 is parallel to plane 41 and is lower than the first portion 40, or at least farther away from the positioned IC chip 20. Joining the first portion 40 and the second portion 42 is a third portion 44. In this exemplary embodiment, the third portion 44 defines a frustum-shaped or frustoconical wall that slopes toward the center of the socket contact 32 from the first portion 40 to the second portion 42. In doing so, this socket contact head 38 offers a continuous contact region along an entire cross-sectional circumference C of the chip's contact 28. This can be seen better in the top-down view of Figure 3. Without limiting the invention, it is believed that by providing such a continuous contact region, any force biasing the chip contact 28 and the socket contact 32 toward each other is distributed, thereby helping to maintain the integrity of the chip contact 28. It is possible that the compressive force applied to the chip contact 28 may be enough to deform it. In that case, the chip contact 28 may flatten against the third portion 44 and perhaps against the second portion 42 as well. This would serve to increase the contact region without inflicting the damage that prior art contacts would cause with their sharp pikes and corners. It should be further noted that, in this embodiment and from this viewpoint, the first portion 40 is annular, or ring-shaped.

Despite the benefits from the area of connection offered by the exemplary embodiment above, it may not be necessary to provide connection along the entire circumference C. Accordingly, the current invention includes within its scope electrical connectors having heads that define polygons in a top-down view. Figure 4A, for example, illustrates a socket contact head 138 comprising a triangular first portion 140,

second portion 142, and third portion 144. Assuming the chip contact 28 is still a semi-spherical solder ball, then electrical connection may occur at three points P1, P2, and P3, along a particular cross-sectional circumference C. Figure 4B depicts yet another socket contact head 238 having a rectangular first portion 240, second portion 242, and third portion 244. Accordingly, electrical connection may occur at four points P4-P7 along a particular cross-sectional circumference C. While the biasing force will be distributed to fewer points in the Figure 4 embodiments in comparison to Figure 3, it should be noted that the contact points P1-P3 and P4-P7 occur on planar areas of the socket contact heads 138 and 238. As a result, deformation of the chip's contact 28 will be minimal.

In the embodiments discussed above, the socket contact heads 38, 138, and 238 have been sized so that only the third portion 44, 144, or 244 is configured to touch the chip contact 28. However, other embodiments are included wherein the head of the electrical connector is sized differently in relation to the chip's contact. In Figure 5A, a socket contact head 338 is sized and shaped to allow for connection not only along the cross-sectional circumference C but also at a point B at the bottom of the chip contact 28. In Figure 5B, socket contact head 438 is sized and shaped to initially touch point B at the bottom of the chip contact 28. Once again it is possible that some deformation of chip contact 28 will occur as it is pressed against socket contact head 438, thereby increasing the area of contact. However, since chip contact 28 is abutting a generally flat plane 442, deformation will not be as damaging as it would be with prior art socket contact heads.

As shown in Figure 6A, a socket contact head 538 can also be sized so that the chip contact 28 touches the socket contact head 538 where the first portion 540 and third portion 544 meet. In the Figure 6A embodiment, the area where these two portions 540 and 544 meet defines a corner 500. As a result, it may be desirable in certain embodiments to provide a more rounded area 600, as seen in Figure 6B, representing the transition from the first portion 640 to the third portion 644 of socket contact head 638. Further, Figure 6C's embodiment demonstrates that it may be beneficial in some embodiments to include an area 700 providing a more gradual or rounded transition from

the third portion 744 to the second portion 742. Moreover, it is not required in some embodiments that the first and second portion be planar. The socket contact head 838 in Figure 6D comprises a first portion 840 that curves outward in a convex manner -- toward the positioned IC chip 20 and its contact 28. On the other hand, the second portion 842 and third portion 844 curve inward in a concave fashion -- away from the positioned IC chip 20 and its contact 28. As a result, the portions 840, 842, and 844 define a contact surface 800 that is generally if not completely complimentary to the shape of the chip contact 28. Specifically, the curved shape of surface 800 corresponds to the curved shape of the chip contact 28.

However, it may be helpful in some embodiments to maintain the planarity of at least the first portion 40. Figure 7 depicts the socket contact head 38 depicted in Figure 2 with a different chip contact 928. In this case, chip contact 928 is planar, as may be found in Land Grid Array (LGA) packages. In LGA packages, a plurality (array) of contact pads ("lands") are used to communicate with the packaged die circuitry. As is preferred, the planar first portion 40 of the socket contact head 38 corresponds to the planar chip contact 928.

In the embodiments described above, it is noted that the contact head's perimeter - or portion of the contact head that is outermost from the central longitudinal axis of the contact -- is also the "highest" area of the head or farthest from the body of the contact. In certain circumstances, the outermost portion could also be described as being closest to the site in which the contact of an IC chip will occupy while being housed in the socket. In addition, because the remainder of the head declines and/or converges toward the central longitudinal axis, these exemplary embodiments can be considered to be defining a central or inner recess or cavity.

In many embodiments, an electrical connector head such as the socket contact heads described above is preferably made of an electrically conductive material. More preferably, the embodiments are made of metal. Exemplary materials for the electrical

connector head include gold, copper, beryllium copper, and stainless steel. The shape of the electrical connector head may be formed through chemical etching techniques – including wet or dry (plasma) etching – or through stamping. Further, the head may be integral to the body of the electrical connector or may be a discrete part that is attached to the body. For example, it is possible to shape the head by die-stamping a metal sheet, then attaching the completed head to an electrical connector body using a conductive adhesive, such as a Silver-based material (Silver Filled Conductive Chip Adhesive is a conductive ink composed of silver flakes in an epoxy base which can be purchased from Ablestick Laboratories of Gardena, CA). In some exemplary embodiments, it is preferable to choose a metal type and thickness so that flexibility in the head, if any, does not result in any pinching action against the chip contact upon biasing the IC chip and socket contact against each other.

As stated above, the electrical contact head may be associated with an electrical contact body that is already known in the art. In the context of socket contacts, for example, Figure 8 illustrates the socket contact head 38 as part of a pogo pin. The socket contact head 38 is connected to, if not an integral part of, an outer shell 48. The socket contact head 38 is also connected to an inner shaft 50 through a spring 52. However, if the outer shell 48 is made of an electrically conductive material, then the entire shell 48 is available to receive current, when all that is really needed is for current to travel from the head 38 to the shaft 50 through the spring 52 (as well as in the reverse direction). In addition, the hole 30 must be wide enough to accommodate the diameter of the shell 48. As technology allows for smaller chip contacts 28 that may then be more closely packed together, it is desirable to densify the socket holes 30 in a corresponding manner. The additional width needed for the outer shell 48 runs counter to that desire.

Accordingly, the current invention includes electrical contacts that dispense with an outer shell. As one example, Figure 9 depicts a socket contact 1032 comprising a socket contact head 38 coupled to a shaft 1050 through a spring 1052. The spring 1052, in turn, has sections defining varying widths. For instance, spring 1052 comprises a first

section 54 and second section 58, whose coils define a circle having a diameter of about 1 mil; as well as a third section 56 having coils that define a circle having a diameter of about two mils. The third section 56 is wide enough to contact the socket's body 24. The absence of an outer shell allows for a narrower hole 30 and therefore allows for a denser
5 array of holes 30 in the socket body 24.

Another electrical contact body that is known in the art is the buckle beam, and the current invention includes electrical contact heads such as the ones described above attached to such a body. However, to avoid the problems associated with buckle beams,
10 the current invention also includes within its scope embodiments such as the one in Figure 10, wherein a socket contact 1032 comprises a socket contact head 38 and a tube 60 having at least one aperture 62. Thus, when a compressive force is applied to the socket contact 1032, at least some of that force will cause the tube 60 to collapse in on itself, initiating the closure of the aperture 62, rather than cause the tube 60 to buckle
15 laterally. Thus, hole 30 need not be as large as when it accommodates buckle beams. The tube is nevertheless resilient enough to generally return to its pre-compression shape once the compressive force eases. Further, the tube 60 is configured to fit snugly against the socket body 24 somewhere along its length. Other embodiments have a plurality of apertures, such as Figure 11, wherein two apertures, 62 and 64, appear at the same depth but on different sides of the tube 60. Figure 12A depicts two apertures, 62 and 66, at
20 different depths along the tube 60. The tube 60 in these and other embodiments are preferably made of metal such as gold, copper, beryllium copper, or stainless steel. The aperture or apertures can be formed by sawing. In addition, since it is also preferred to make the socket contact head from metal, it is possible to form the head 38 and tube 60
25 from the same piece of metal.

Still other embodiments include other contacts with bodies defining a generally continuous profile but for at least one deformation or deviation. For example, apertures of different shapes may be formed. While the contacts in Figures 10, 11, and 12A define
30 a rectangular profile with a deformation in the form of a second, smaller rectangle (or a

slit), it is possible to define a different deformation by using a different saw blade, by using a particular etching technique, or simply by stamping a dent into the contact body. Figure 12B exemplifies such a different deformation – in this case a semi-circular deformation 62' is defined from a body 60' having a generally rectangular profile defined by body's cylindrical shape. Moreover, the contact body in the embodiments described above, as well as others, can be hollow. Methods for making such a hollow body can be similar to those known in the art for making the outer shell 48 of the pogo pin depicted in Figure 8. A hollow body allows embodiments such as the one depicted in Figure 12C, wherein metal strips 64' and 66' integrally extend from and join cylindrical portions of the contact body 60'. That embodiment can be formed by sawing on opposite ends of the hollow body, as depicted in Figure 12D. Figure 12D is a top-down cross sectional view of the contact in Figure 12C. Saw blades 68' move in the direction indicated by arrows 70', thereby defining strips 64' and 66' from the cylindrical shell body 60'. Saw blades 68' can represent two blades that saw the body 60' simultaneously or one saw blade that saws the body 60' at different places and at different times. Figure 12E is another side view of this embodiment, similar to Figure 12C, only at a slightly different angle than that of Figure 12C. In Figure 12E, the strip 64' is closer to the viewer than strip 66'. In response to a compressive force along the length of the contact body 60', the strips 64' and 66' can buckle, allowing the body 60' to at least partially close the gap 72'. In yet another embodiment, seen in Figure 12F, the strips 64' and 66' may be deformed or "pre-dented" through stamping or other methods, to encourage an inward collapse in response to compression. Once again, these embodiments can return to their shape as the compression eases.

While all-metal electrical contacts are preferable in terms of electrical conductivity, it may sometimes be preferable to use semiconductive materials for at least the body of the electrical contact, as this allows for the use of fabrication techniques that support scaling on par with the techniques used to define the contact pitch in the IC chip that is to be tested. Figures 13A through 13H demonstrate such fabrication techniques that may be used in embodiments of the current invention to form an electrical contact.

Figure 13A shows a semiconductor substrate 68 that has been patterned on the top and bottom with photoresist 70 so as to define a plurality of contact bodies. For purposes of explanation, it is assumed that the substrate is made of silicon that has been doped to encourage electrical conductivity. Next, as seen in Figure 13B, the shape of the top and bottom of the in-process contact bodies are defined through etching. Figure 13B indicates that an anisotropic etch has been performed on the top and bottom. The fact that plateaus 72 remain on the bottom suggests that the anisotropic etch on the bottom was either shorter in time or involved a lower etch rate than the anisotropic etch on the top; or that the openings defined by the photoresist on the bottom were larger than the openings on top. Partially defining the contacts also establishes the placement of each prospective contact relative to the other prospective contacts. Any silicon remaining between the designated contact sites continues to determine the alignment of each contact in the array of contacts until that silicon is replaced with another material. Such a step is illustrated in Figure 13C, where the photoresist is removed and the position of each in-process contact is maintained relative to the other in-process contacts, in this case through the application of a z-axis elastomer 74 to the bottom of the substrate. The z-axis elastomer 74 is an adhesive material that is capable of conducting electricity along a dimension in response to pressure applied along that dimension. The direction of pressure is usually designated as being aligned with a z-axis, wherein the elastomer sheet is generally parallel to a plane defined by an x and y axis (and wherein the x, y, and z axes are 90° from each other). Such an elastomer is generally nonconductive along the x and y axes.

Once the alignment of the in-process contacts has been reinforced, the contacts are then singulated by removing the remaining silicon interconnecting the in-process contacts. One option for doing so is shown in Figure 13D, wherein additional photoresist 76 is patterned to protect the tops of the in-process contacts, and the substrate 68 subsequently undergoes an isotropic etch to form the sidewalls of the in-process contacts. Preferably, the isotropic etch is continued to completely separate the contacts 1232, as depicted in Figure 13D. Alternatively, the isotropic etch may be used to partially define

the sidewalls (Figure 13E), with an anisotropic etch completing the singulation (Figure 13F). Once the additional photoresist 76 has been removed, Figure 13G shows that the array of discrete contacts 1232, along with the z-axis elastomer 74 maintaining their placement, may then be moved to a substrate 78 such as a PCB having conductive leads 80 that end under the contacts 1232. When the contacts 1232 undergo compression, the z-axis elastomer 74 provides resiliency as well as electrical communication between the contacts 1232 and the leads 80. It may also be desirable in some embodiments to deposit insulation 82 between the contacts 1232 for added stability. This can be accomplished with a blanket deposition of an insulating layer followed by an etchback, with photoresist protecting the contacts. The end result is the socket 1322 illustrated in Figure 13H. As with previous sockets, an IC chip's contacts will connect with the socket's contacts 1232, and the PCB's conductive leads 80 can be wire bonded to test equipment for testing the IC chip.

Variations of the processes described above also fall within the scope of the current invention. For example, sidewall definition and singulation of the contacts can be accomplished with a saw such as those used to singulate dice from a wafer. In addition, there are ways to retain the alignment of the contacts 1232 other than using the z-axis elastomer 74. For example, after the step illustrated in figure 13B, an alternate step shown in Figure 14A may be taken. That figure illustrates that the photoresist 70 has been removed and another layer of resist 84 has been applied and patterned to protect the tips of the in-process contacts. Figure 14A further indicates that the sidewalls of the in-process contacts have been defined, either through etching or sawing. Subsequently, the insulation layer 82 is provided to a desired height, and the resist 84 is removed (Fig. 14B). In this embodiment, it is the insulation layer 82 that maintains the alignment of the in-process contacts. Singulation may then be completed by etching or sawing from the bottom of the substrate 68, the result of which is seen in Figure 14C. The z-axis elastomer 74 may still be used, but in this embodiment, it may be initially deposited on the substrate 78, with the singulated contacts 1232 and insulation 82 being placed thereover.

In addition, a metallization step may be added to make the tip of the contacts 1232 more electrically conductive. Moreover, it should be noted that the tip of the contacts may be formed in accordance with the configurations described above for providing a contact head with a groove or recess or cavity or defining a cup shape, with the v-shaped
5 recesses depicted in the contacts 1232 of Figure 13H and 14C serving as one example. As another example, the etch time, etch rate, or resist opening could be established, as is known in the art, to define a contact tip that more closely resembles the socket contact head of Figure 2. The result of such a step appears in Figure 15A. A metal layer could then be provided and subsequently patterned using photoresist to define heads 1438 of the
10 in-process contacts. Additional steps as illustrated in Figures 13C-13H may be performed to reach the result depicted in Figure 15C, wherein each contact 1232 has a metallic head 1438 comprising a first portion 1540 defining a plane 1541 and an opening. In this embodiment, the plane 1541 is parallel to the substrate 78. Similarly, a second portion 1542 is parallel to plane 1541 and is lower than the first portion 1540, or at least
15 closer to the substrate 78. Joining the first portion 1540 and the second portion 1542 is a third portion 1544. In this exemplary embodiment, the third portion 1544 defines a frustum-shaped or frustoconical wall that slopes in toward center of the socket contact 1232 from the first portion 1540 to the second portion 1542. As an alternative to using a metallization step, it is also within the scope of the current invention to form a metal head
20 separately and attach it to a silicon contact.

One skilled in the art can appreciate that, although specific embodiments of this invention have been described for purposes of illustration, various modifications can be made without departing from the spirit and scope of the invention. For example, just as
25 embodiments concerning a socket contact head may be associated with prior art socket contact bodies, so too can embodiments of socket bodies be used in conjunction with prior art socket heads. Moreover, concerning embodiments involving the testing of electronic devices, the devices and methods covered by the current invention could be used in tests including burn-in, connectivity checks, open short tests, and multichip
30 module tests, as well as others. As for embodiments addressing what IC chips could be

5

Claims

What is claimed is:

1. An electrical connector, comprising:

- 5 an elongated conductive body defining a central axis and having an end;
 an electrically conductive annular portion at said end concentric to said central
 axis;
 an electrically conductive frustoconical portion extending inward from said
 annular portion toward said central axis; and
10 an electrically conductive planar portion below said annular portion, concentric to
 said central axis, and coupled to said frustoconical portion.

2. The electrical connector in claim 1, wherein said body comprises a pogo pin.

15 3. A socket contact head, comprising:

- a flat area;
 a sidewall extending upward and outward from said flat area; and
 a perimeter portion extending outward from said sidewall; wherein a selection of
 said flat area, said sidewall, said perimeter portion, and combinations
20 thereof is configured to receive an IC chip contact and further configured
 to transmit an electrical signal along a socket contact body.

4. The socket contact head of 3, wherein said sidewall comprises a plurality of planar
walls.

25

5. The socket contact head of claim 4, wherein said sidewall comprises:

- a first planar wall;
 a second planar wall coupled to said first planar wall; and
 a third planar wall coupled to said first planar wall and said second planar wall.

30

6. An electrically conductive contact head, comprising:

an upper portion defining an opening;

a sidewall coupled to said upper portion at a first transition area and decliningly

5 converging from said first transition area;

a lower portion coupled to said sidewall at a second transition area; and

an electrical connection contact area at a selection of said upper portion, said
sidewall, said lower portion, and combinations thereof;

10 wherein a selection of said upper portion, said sidewall, said lower portion, and
combinations thereof is configured to contact a socket contact body.

7. The electrically conductive contact head in claim 6, wherein said electrical connection
contact area defines a circle along said sidewall.

15 8. The electrically conductive contact head in claim 6, wherein said electrical connection
contact area defines a plurality of points along said sidewall.

9. The electrically conductive contact head in claim 6, wherein said electrical connection
contact area comprises:

20 at least a circle along said sidewall; and
at least a point on said lower portion.

10. The electrically conductive contact head in claim 6, wherein said electrical
connection contact area coincides with at least a portion of said upper portion.

25

11. The electrically conductive contact head in claim 6, wherein said electrical
connection contact area coincides with said first transition area.

12. The electrically conductive contact head in claim 11, wherein said first transition area
30 is rounded.

13. A receptacle for an IC chip contact, comprising:

a metal layer having a shape that is at least generally complimentary to said IC

chip contact, wherein said layer comprises:

an outer surface,

a curved middle surface transitioning from said outer surface, and

a curved inner surface transitioning from said middle surface; and

a conductive material in electrical communication with said metal

layer and extending generally unidirectionally from said
metal layer.

14. The receptacle in claim 13, wherein said outer surface comprises a curved surface.

15. An electrical connection device, comprising:

a head defining an inner frustum-shaped recess and sized to accommodate an IC
chip contact; and

a resilient body coupled to said head.

16. The electrical connection device of claim 15, wherein said resilient body comprises:

a doped semiconductor shaft; and

an elastomer material contacting said shaft.

17. The electrical connection device of claim 15, wherein said resilient body comprises a

compressible metallic element.

18. The electrical connection device of claim 17, wherein said resilient body comprises a
tube defining at least one aperture therein.

19. The electrical connection device of claim 17, wherein said resilient body comprises:
a spring coupled to said head; and
a shaft coupled to said spring.

5 20. The electrical connection device of claim 19, wherein said resilient body further comprises a shell coupled to said head and outwardly concentric to said shaft.

21. A pin for a socket, comprising:

a head having a central recess; and

10 a shaft in electrical communication with said head and biased from said head,
wherein said shaft is configured to extend from said socket.

22. The pin in claim 21, further comprising a spring coupled to and interposed between
said head and said shaft.

15

23. The pin in claim 22, wherein said spring defines a plurality of coil circumferences.

24. The pin in claim 23, wherein said spring comprises:

a first section next to said head and defining a first coil circumference;

20

a second section next to said first section and defining a second coil
circumference; and

a third section between said second section and said shaft and defining a third coil
circumference generally equal to said first coil circumference.

25 25. The pin in claim 24 wherein said second coil circumference is greater than said first
coil circumference.

26. The pin in claim 25, wherein said second section of said spring is configured to
contact a nonconductive portion of said socket.

30

27. A socket connector comprising:

a cup-shaped head; and

a resilient tube next to said head and defining at least one aperture in said tube,

wherein said tube is configured to at least partially extend into a socket

hole.

28. The socket connector in claim 27, wherein said tube defines a plurality of apertures at one length along said tube.

29. The socket connector in claim 27, wherein said tube defines a first aperture at a first length along said tube; and a second aperture at a second length along said tube.

30. The socket connector in claim 27, wherein said tube defines a first aperture on a first side of said tube and a second aperture on a second side of said tube.

31. The socket connector of claim 30, wherein said head is integral to said tube.

32. A contact, comprising:

a metal body sized to partially fit within an IC chip socket, wherein said metal

body defines:

a generally continuous profile; and

at least one deformation of said profile.

33. The contact in claim 32, wherein said generally continuous profile comprises a

cylindrical profile; and wherein said deformation comprises a rectangular slit.

34. The contact in claim 32, wherein said deformation comprises a semi-circular aperture.

35. An electrical connector, comprising:

a socket contact head configured to receive an IC chip contact; and

a socket contact body coupled to said head and comprising:

a first portion,

at least one strip integrally extending from said first portion, and

a second portion integrally extending from said at least one strip.

36. The electrical connector in claim 35, wherein said first portion and said second portion are hollow.

37. The electrical connector in claim 36, wherein said first portion and said second portion are cylindrical and define a common central axis.

38. The electrical connector in claim 37, wherein said at least one strip is bent toward said central axis.

39. The electrical connector in claim 37, wherein said at least one strip is configured to bend toward said central axis in response to a compressive force along said central axis.

40. A method of processing an array of contacts, comprising:

defining a general shape for each contact of a plurality of contacts;

maintaining a position of said each contact relative to other contacts in said plurality;

singulating said plurality of contacts; and

attaching said plurality of contacts to a substrate.

41. The method in claim 40, wherein said step of defining a general shape for each contact of a plurality of contacts comprises:

providing a semiconductor substrate having a top and a bottom;

etching said top of said substrate; and
etching said bottom of said substrate.

42. The method in claim 41, wherein said step of defining a general shape for each
5 contact of a plurality of contacts further comprises a step of defining a sidewall for said
each contact.

43. The method in claim 42 wherein said step of defining a sidewall for said each contact
comprises sawing around a location defining said each contact.

10

44. The method in claim 42, wherein said step of defining a sidewall for each contact
comprises etching around a location defining said each contact.

45. A method of forming socket contacts, comprising:
15 forming a plurality of interconnected silicon contacts;
applying an alignment-preserving material to said plurality of interconnected
silicon contacts; and
disconnecting said plurality of interconnected silicon contacts.

20 46. The method in claim 45, wherein:
said step of forming a plurality of interconnected silicon contacts comprises:
etching two silicon contacts from a silicon substrate, and
retaining a portion of silicon between said two silicon contacts; and
said step of disconnecting said plurality of interconnected silicon contacts
25 comprises removing said portion of silicon.

47. The method in claim 46, wherein said step of applying an alignment-preserving
material comprises a selection of:
applying a z-axis elastomer on a first side of said plurality of interconnected
30 silicon contacts; and

applying an insulator on a second side of said plurality of interconnected silicon contacts.

5 48. A method of forming an electrical contact, comprising:

providing a planar silicon substrate;

forming an electrical contact surface from said substrate;

depositing a metallic layer over said surface;

patterning a contact head from said metallic layer; and

10 forming a discrete electrical contact body from said substrate.

49. The method in claim 48, wherein said step of forming an electrical contact surface comprises:

anisotropically etching a cavity from said substrate; and

15 protecting a first portion of said substrate from said etching.

50. The method in claim 49, wherein said step of forming an electrical contact surface further comprises retaining a planar second portion of said substrate under said cavity.

20 51. The method in claim 50, wherein said step of patterning a contact head from said metallic layer comprises:

protecting a section of said metallic layer overlying said first portion of said substrate, an anisotropically etched portion of said substrate, and said second portion of said substrate with an etch resistant material; and

25 etching an unprotected section of said metallic layer.

52. A socket contact formation process, comprising:

forming a contact head from a conductive material;

forming a contact body from semiconductive material; and

30 joining said contact head and said contact body.

53. The process in claim 52, wherein:

said step of forming a contact head comprises stamping a metal element;

said step of forming a contact body comprises etching silicon; and

said step of joining said contact head and said contact body further comprises
adhering said contact head onto said contact body.

54. The process in claim 52, wherein said step of joining said contact head and said
contact body further comprises depositing a metal over a silicon surface.

55. A method of forming a socket, comprising:

providing a semiconductor substrate;

defining an arrangement of a plurality of socket contacts from said substrate;

preserving said arrangement;

providing a substrate having a plurality of conductive leads; and

attaching said plurality of socket contacts to said substrate, wherein at least one
socket contact is over at least one conductive lead.

56. The method in claim 55, wherein said step of attaching said plurality of socket
contacts to said substrate comprises attaching said plurality of socket contacts to said
substrate with a conductive elastomer.

57. The method in claim 56, wherein said step of attaching said plurality of socket
contacts to said substrate with a conductive elastomer comprises:

placing said elastomer onto said substrate; and

placing said plurality of socket contacts onto said elastomer.

58. The method in claim 56, wherein said step of attaching said plurality of socket
contacts to said substrate with a conductive elastomer comprises:

placing said elastomer onto an underside of said plurality of socket contacts; and

placing said substrate onto an underside of said elastomer.

59. The method in claim 58, wherein said step of preserving said arrangement comprises preserving said arrangement with said elastomer.

5

60. A method of enabling electrical communication between an IC chip and a printed circuit board, comprising:

defining a deformation within a metal tube;

interposing said metal tube between said IC chip and said printed circuit board;

10

and at least partially closing said deformation in response to compression applied to a longitudinal axis of said metal tube.

61. The method in claim 60, further comprising:

inserting said IC chip into a socket;

15

including said metal tube as part of said socket; and

inserting said socket into said printed circuit board.

62. A method of supporting electrical communication through a socket between an IC chip and a printed circuit board, comprising:

20

interposing a semiconductive shaft between said IC chip and said printed circuit board;

connecting said shaft to said printed circuit board with an adhesive material; and

allowing electrical conductivity through said adhesive material in response to a compression between said shaft and said printed circuit board.

25

Abstract of the Disclosure

In a socket used to house semiconductor die during testing, a recessed socket contact is provided that avoids pinching the die's contacts. Also provided are socket
5 contacts that allow for smaller socket holes and, therefore, denser arrays of socket contacts. In one embodiment, the body of the socket contact comprises a head, a spring coupled to the head, and a shaft coupled to the spring; no outer shell is needed for the spring, as the non-conductive sides of the socket hole serve that function. In another embodiment, the body of the socket contact comprises a metal shaft having an aperture.
10 Compression causes the shaft to close around the slit, thereby decreasing the amount of lateral buckling. In yet another embodiment, semiconductor fabrication techniques are used to construct a dense array of contacts.

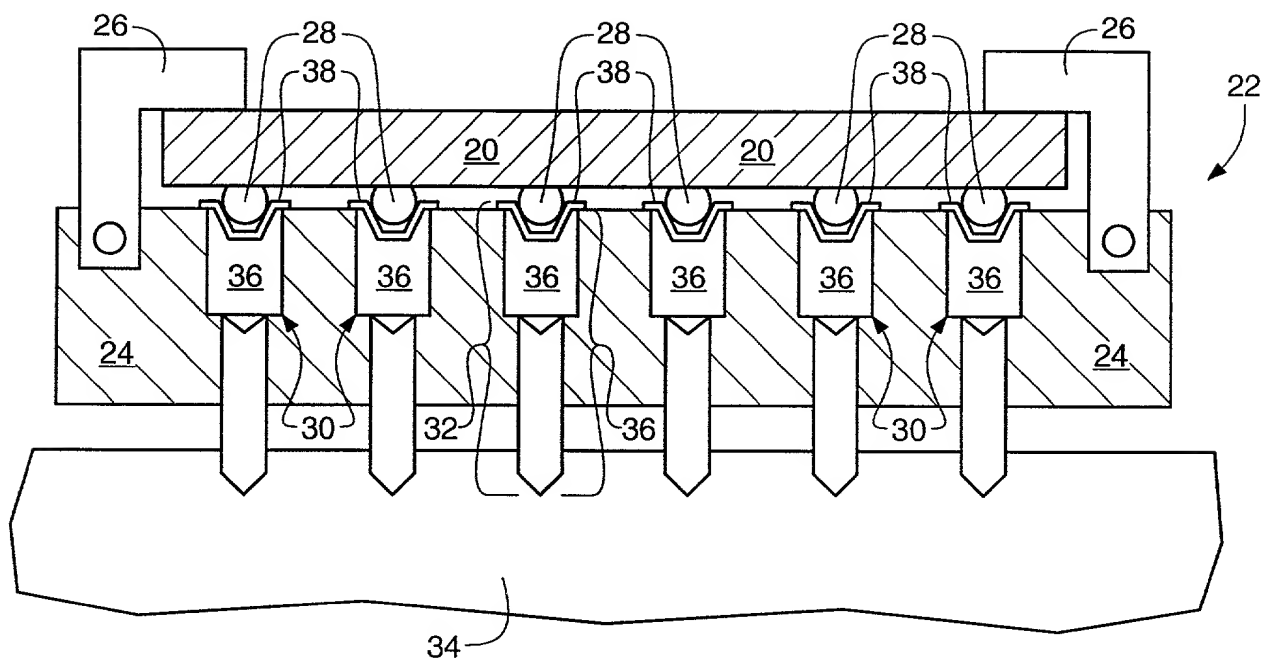


FIG. 1

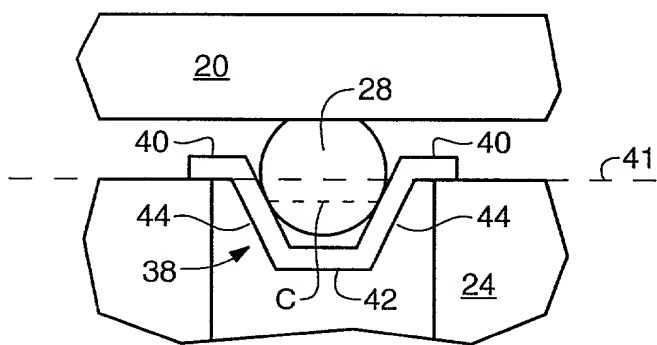


FIG. 2

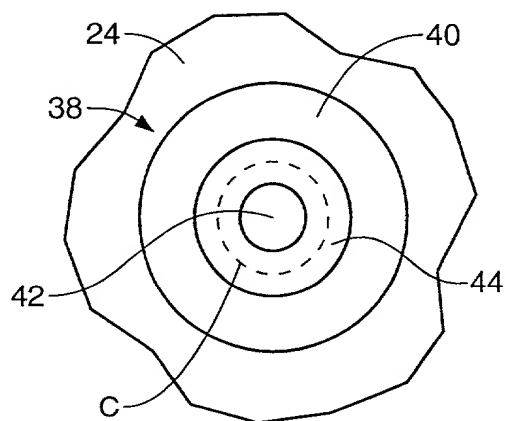


FIG. 3

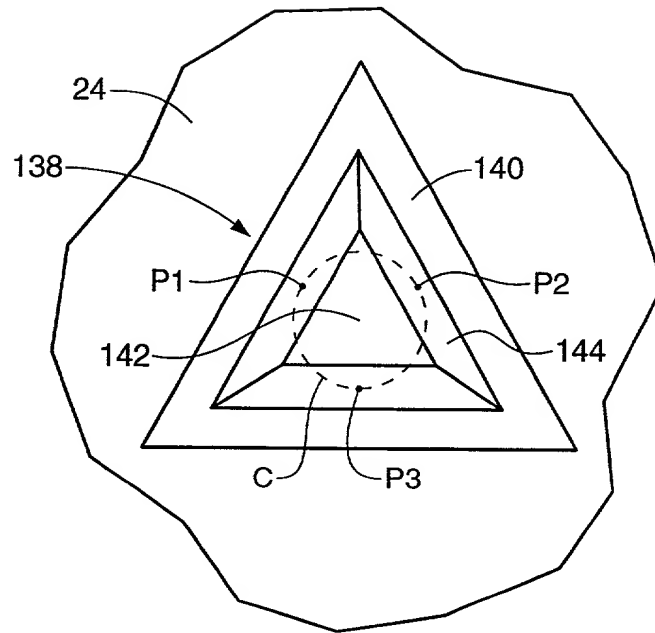


FIG. 4A

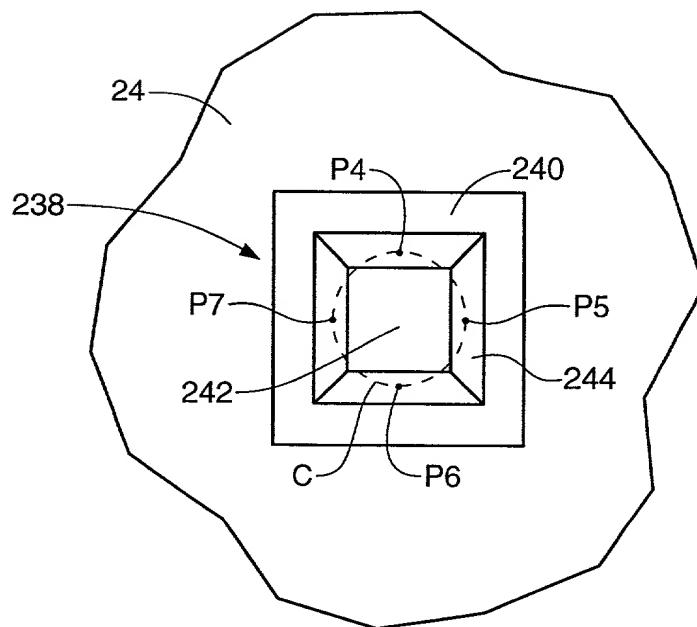
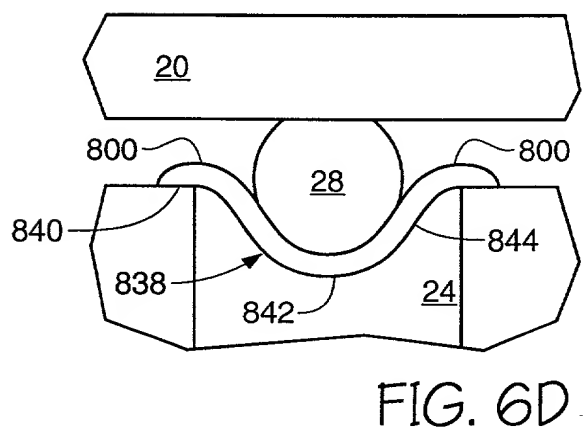
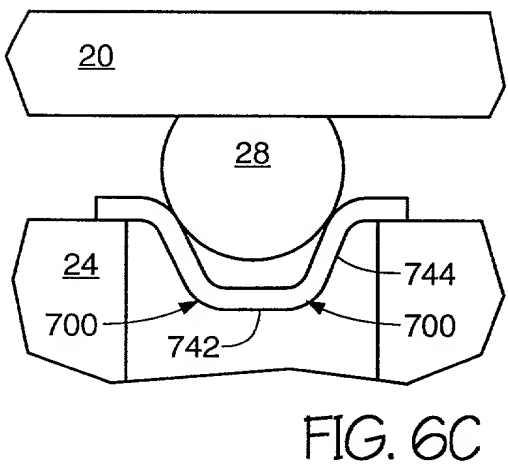
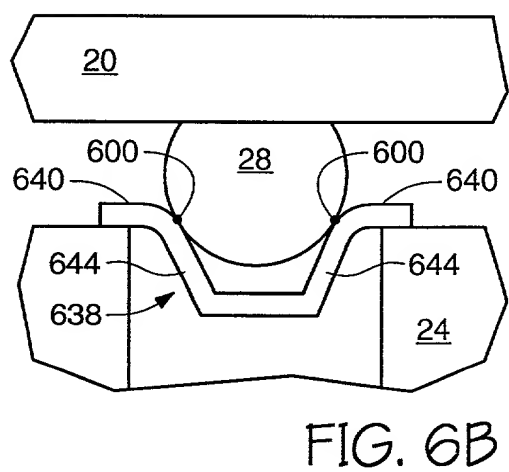
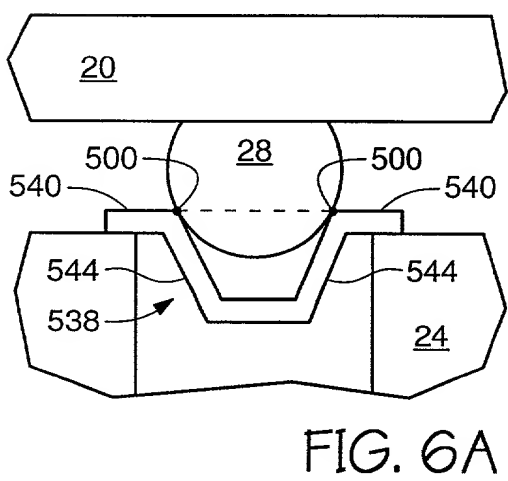
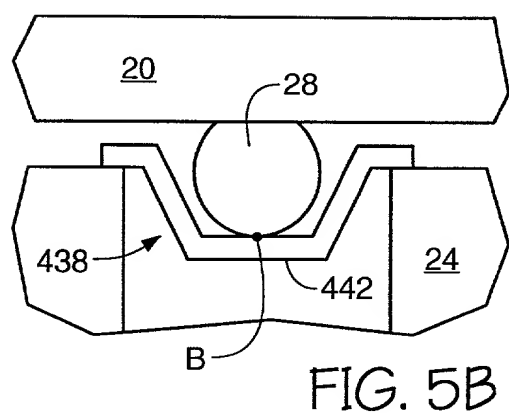
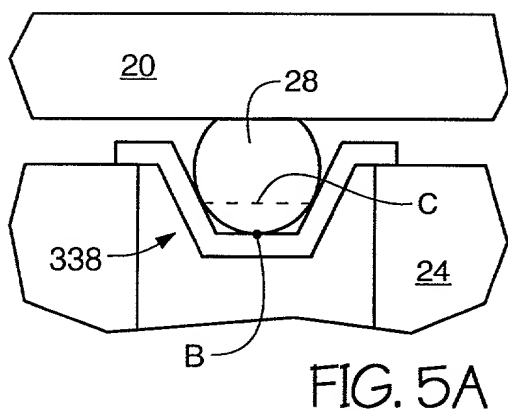


FIG. 4B



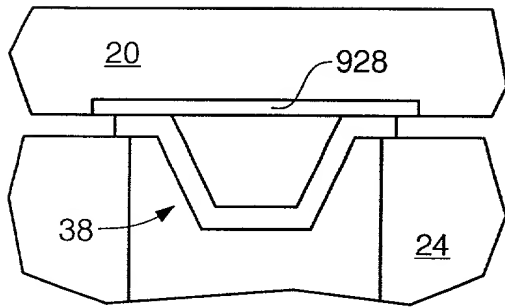


FIG. 7

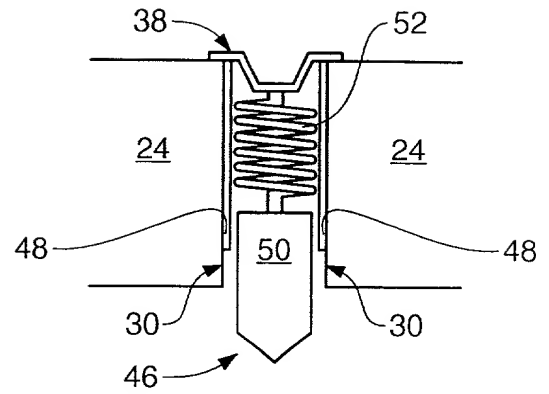


FIG. 8

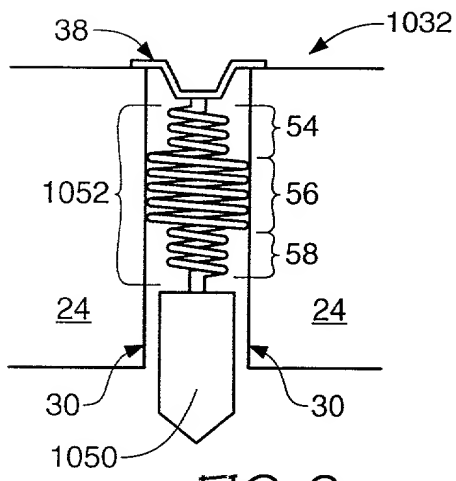


FIG. 9

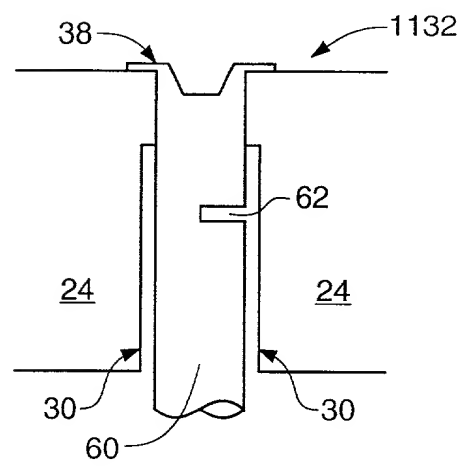


FIG. 10

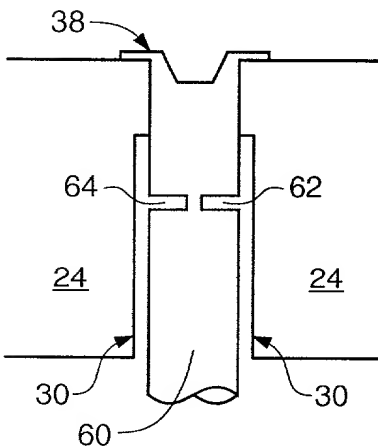


FIG. 11

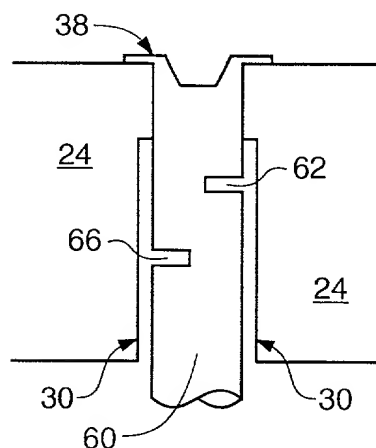


FIG. 12A

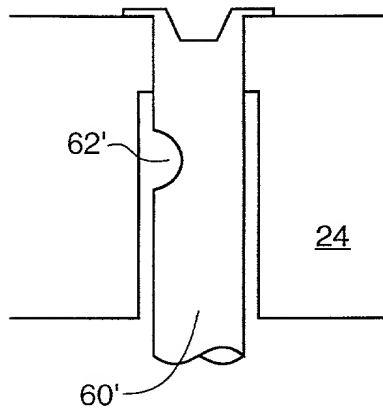


FIG. 12B

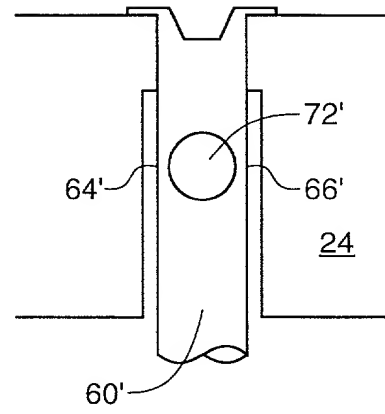


FIG. 12C

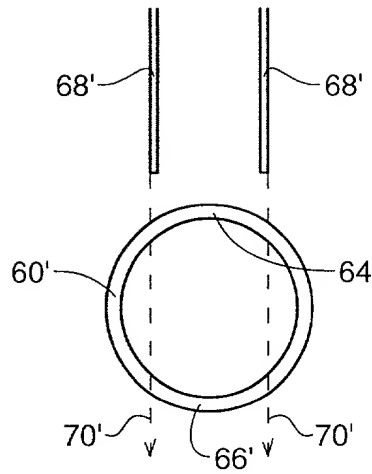


FIG. 12D

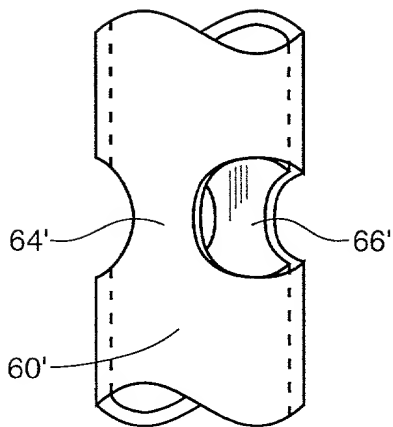


FIG. 12E

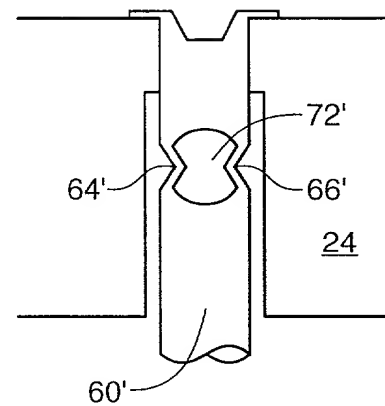


FIG. 12F

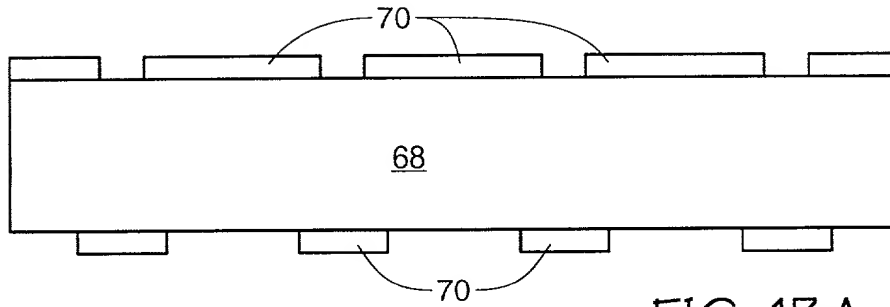


FIG. 13A

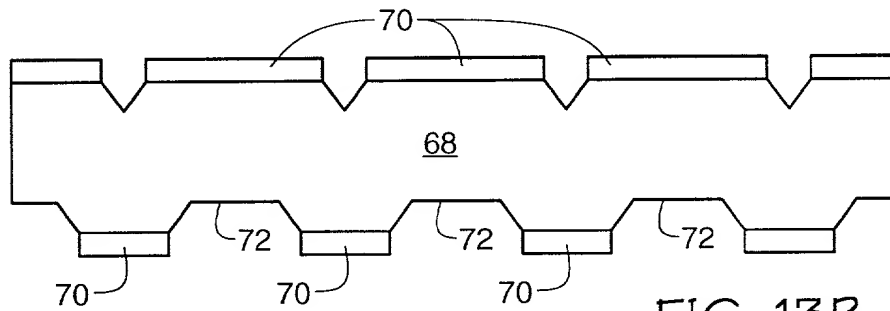


FIG. 13B

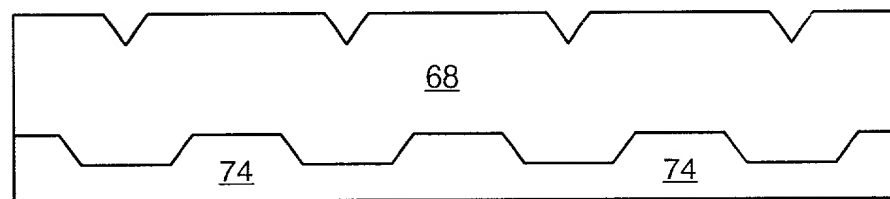


FIG. 13C

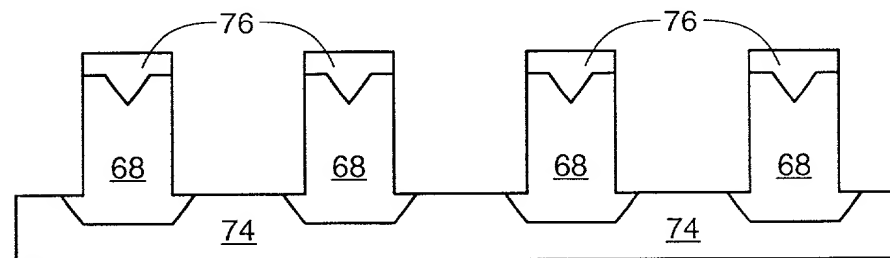


FIG. 13D

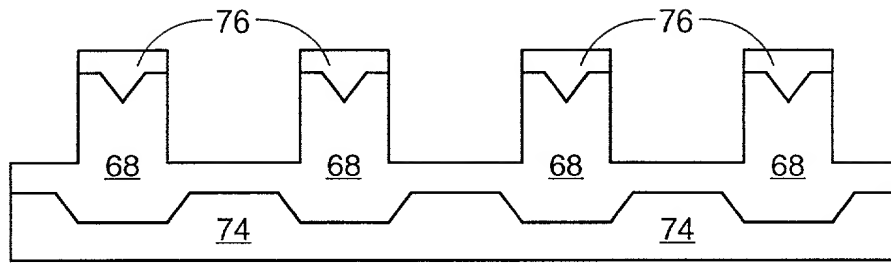


FIG. 13E

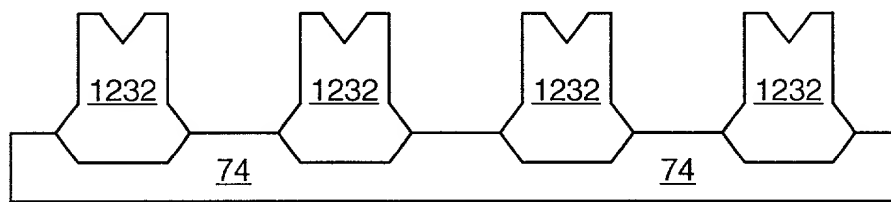


FIG. 13F

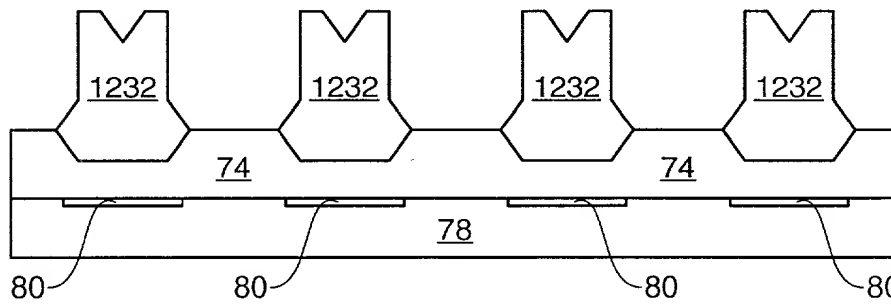


FIG. 13G

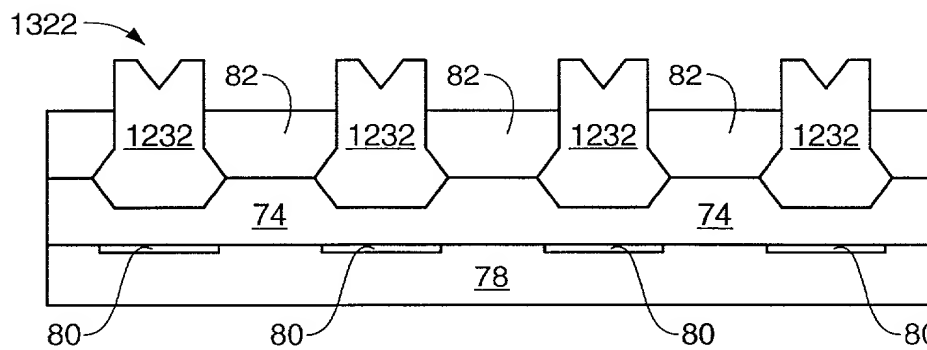


FIG. 13H

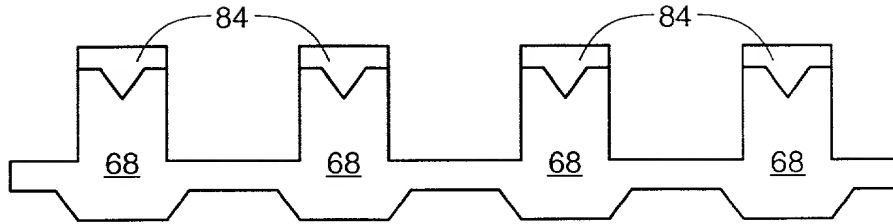


FIG. 14A

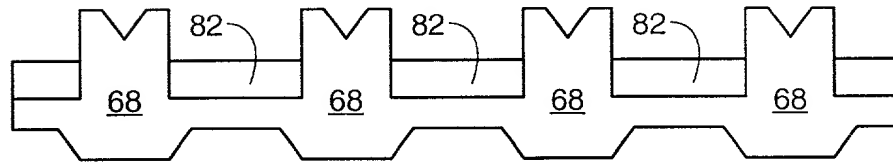


FIG. 14B

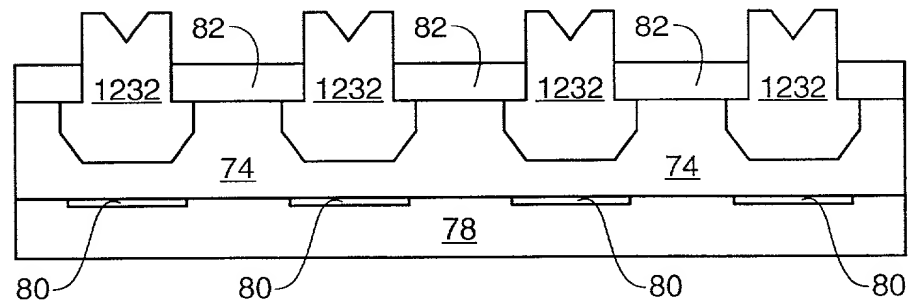


FIG. 14C

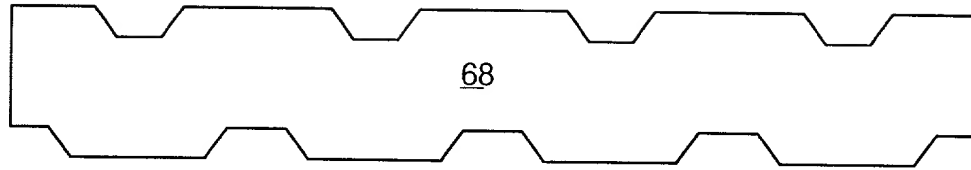


FIG. 15A

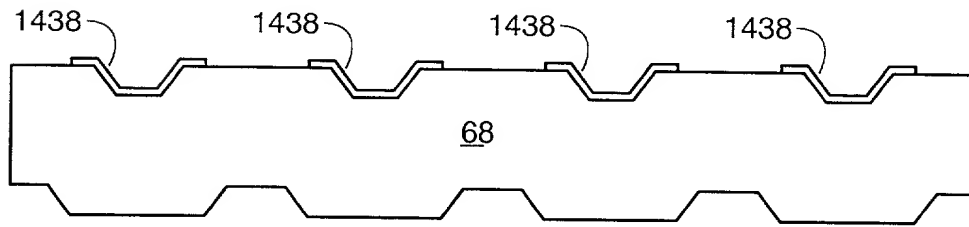


FIG. 15B

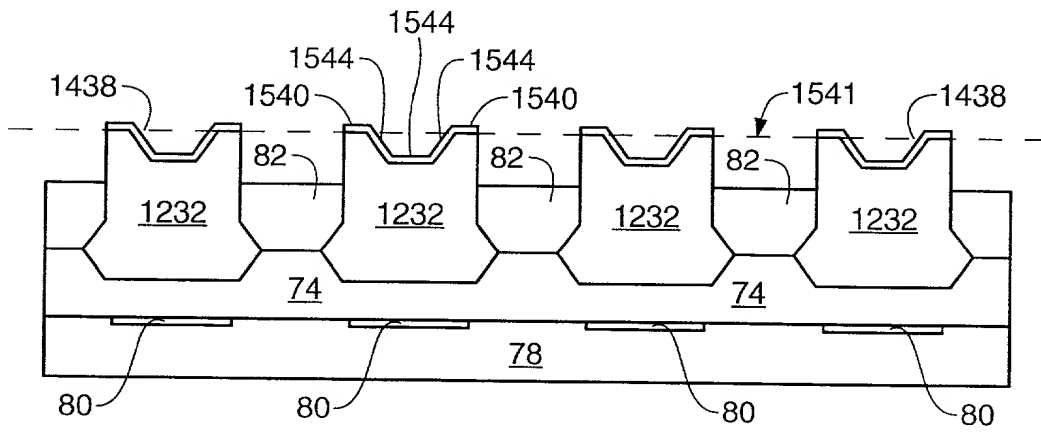


FIG. 15C

DECLARATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled ELECTRICAL CONNECTOR, the specification of which:

X is attached hereto.

_____ was filed on _____, as Application Serial No. _____.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims.

I acknowledge the duty to disclose information which is material to patentability of the subject matter claimed in this application as "materiality" is defined in Title 37 of the Code of Federal Regulations, § 1.56.

I hereby claim the benefit of any earlier filing date in the United States to which I am entitled under Title 35 of the United States Code, § 120 and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35 of the United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 of the Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

(Application Serial No.)

(Filing Date)

(Status)

Send correspondence to:

Charles Brantley
Mail Stop 525
Micron Technology, Inc.
8000 S. Federal Way
Boise, Idaho 83716
(208) 368-4557

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Title 18 of the United States Code, § 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of first or sole inventor: Salman Akram

Inventor's Signature: _____

(First, Middle Initial, Last)

Date: _____

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United States of America

Citizenship: _____

Pakistan

Post Office Address: _____

Same as residence address

Full name of additional inventor: David R. Hembree
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Citizenship: USA
Post Office Address: Same as residence address

Full name of additional inventor: Warren M. Farnworth
Inventor's Signature: Warren M. Farnworth
(First, Middle Initial, Last)
Date: 3-10-1999
Residence Address: 2004 S. Banner
City, State, Country: Nampa, ID 83686-7271 United States of America

Citizenship: USA
Post Office Address: Same as residence address

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Salman Akram, David R. Hembree and
Warren M. Farnworth

Serial No.:

Filed: August 31, 2000

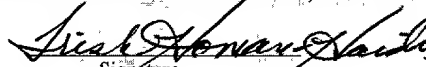
For: ELECTRICAL CONNECTOR

§
§ Group Art Unit:
§
§ Examiner:
§
§ Atty. Docket: 97-1102.05
§
§
§

STATEMENT CONCERNING DELETION OF INVENTOR UNDER 37 CFR 1.63(d)(2)

Assistant Commissioner for Patents
Washington, D.C. 20231

"Express Mail" MAILING LABEL NUMBER EL679497838S
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I HEREBY CERTIFY THAT THIS PAPER IS BEING DEPOSITED
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COMMISSIONER FOR PATENTS, WASHINGTON, D.C. 20231.


Signature

Dear Sir:

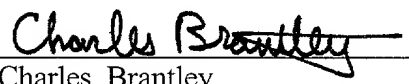
As a result of the claim cancellations made in the Preliminary Amendment, the following
person is no longer inventors in the above-captioned application:

David R. Hembree

Accordingly, the remaining Applicants request the deletion of this name from this application.

Respectfully submitted,

Date: 8/29/00


Charles Brantley
Reg. No. 38,086
Micron Technology, Inc.
8000 S. Federal Way
Boise, ID 83716-9632
(208) 368-4557
ATTORNEY FOR APPLICANTS

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Salman Akram, David R.
Hembree, and Warren M. Farnworth
Serial No.:
Filed: August 31, 2000
For: ELECTRICAL CONNECTOR

§ Atty. Docket: 97-1102.05
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20231.

Trick Homer-Adair
Signature

ELECTION UNDER 37 C.F.R. §§ 3.71 AND 3.73 AND POWER OF ATTORNEY

Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

The undersigned, being Assignee of the entire interest in the above-identified application by virtue of an Assignment recorded in the United States Patent and Trademark Office as set forth below or filed herewith, hereby elects, under 37 C.F.R. § 3.71, to prosecute the application to the exclusion of the inventor(s).

The Assignee hereby revokes any previous Powers of Attorney and appoints: Charles B. Brantley, II, Reg. No. 38,086; Michael L. Lynch, Reg. No. 30,871; Walter D. Fields, Reg. No. 37,130; Kevin D. Martin, Reg. No. 37,882; and David J. Paul, Reg. No. 34,692 as its attorney or agent, with full power of substitution and revocation, to prosecute the application, to make alterations and amendments therein, to transact all business in the Patent and Trademark Office in connection therewith, to receive any Letters Patent, and for one year after issuance of such Letters Patent to file any request for a certificate of correction that may be deemed appropriate.

Pursuant to 37 C.F.R. § 3.73, the undersigned duly authorized designee of Assignee certifies that the evidentiary documents have been reviewed, specifically the Assignment to MICRON TECHNOLOGY, INC., referenced below, and certifies that to the best of my knowledge and belief, title remains in the name of the Assignee.

Assignment:

 Filed concurrently herewith for
recording, a copy of which is
attached hereto.

X Previously recorded on: 3/10/99, at Reel:
9816, Frame: 0143.

Please direct all communications as follows:

Charles B. Brantley, Mail Stop 525
MICRON TECHNOLOGY, INC.
8000 S. Federal Way
Boise, ID 83716-9632
(208) 368-4557

ASSIGNEE: MICRON TECHNOLOGY, INC.

Date: 8-30-00

By: *[Signature]*
Michael L. Lynch, Reg. No. 30,871
Chief Patent Counsel